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by Brian E. Placzankis, Chris E. Miller, Paul F. Buckley, and John H. Beatty

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Box Panel specimens of e-coated steel painted with Chemical Agent Resistant Coating (CARC) and treated with CARWELL commercial corrosion inhibitor were exposed to GM 9540P cyclic corrosion and to the vehicle accelerated corrosion test track at the Aberdeen Test Center at Aberdeen Proving Ground, MD. The box panels were chosen to simulate closed interior spaces found on typical military vehicles such as door panels on trucks. Panels with and without the CARWELL pretreatment were exposed for 100 cycles of GM 9540P. CARWELL treated panels were placed on the truck and monitored for crevice corrosion in the lap joint to determine the reapplication interval of the CARWELL treatment. No evaluation of the effectiveness and suitability of using CARWELL on exterior, unenclosed surfaces was performed.

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Abstract

Box Panel specimens of e-coated steel painted with Chemical Agent Resistant Coating (CARC) and treated with CARWELL commercial corrosion inhibitor were exposed to GM 9540P cyclic corrosion and to the vehicle accelerated corrosion test track at the Aberdeen Test Center at Aberdeen Proving Ground, MD. The box panels were chosen to simulate closed interior spaces found on typical military vehicles such as door panels on trucks. Panels with and without the CARWELL pretreatment were exposed for 100 cycles of GM 9540P. CARWELL treated panels were placed on the truck and monitored for crevice corrosion in the lap joint to determine the reapplication interval of the CARWELL treatment. No evaluation of the effectiveness and suitability of using CARWELL on exterior, unenclosed surfaces was performed.

Keywords: corrosion, inhibitor, automotive, cyclic salt spray

Introduction

The periodic application of a rust preventative water displacing compound can be an effective tool in corrosion prevention and control in both commercial and tactical vehicles. TACOM sponsored field testing has demonstrated the effectiveness of a commercial product (CARWELL), especially in hollow interior cavities (doors, etc.) where the compound penetrates into corrosion prone areas such as lap joints and areas near tack weldments. For commercial applications, the manufacturer suggests a periodic application rate of once per year, and TACOM has recommended an application rate of twice per year in severely corrosive environments for tactical vehicles. The Program Manager of the FMTV (Family of Medium Tactical Vehicles), in conjunction with the Aberdeen Test Center, has initiated full-scale durability/corrosion testing of the FMTV at Aberdeen Proving Ground, MD. The testing is patterned after corrosion durability tests performed on automobiles by General Motors, but it has been adapted for use on tactical vehicles. The complete test is designed to simulate 22 years of typical driving and corrosion exposures. Though the acceleration of typical corrosion processes during the test is fairly well known (in comparison to the GM standard test, GM9540P), the accelerated rate of depletion of the oils and corrosion inhibitors is unknown. The severe salt sprays, water troughs, and high temperature humidity cycles encountered during the test should accelerate the loss of the preventative compound. Therefore, the "application rate" during accelerated testing needs to be determined. ARL assisted the Aberdeen Test Center (ATC) in empirically determining the correct application rate to use during the Accelerated Corrosion Testing (ACT). This was accomplished through the use of dummy samples attached to the FMTV to simulate an interior hollow cavity.

Experimental Procedure

E-coated steel panels[1] with CARC[2] topcoat were received from Ocean City Research (OCR) for testing (Figure 1). Of the 24 received, 16 were treated with CARWELL rust inhibitor by ATC with 8 panels each designated for mounting on the test vehicle and for the GM 9540P test chamber. The remaining 8 panels were left untreated and were also exposed to GM 9540P in the test chamber. In order to facilitate periodic viewing of the lap joint crevice, the spot welds located at the top portion of the box panel were removed via drilling allowing direct line of sight observation.

For the test track exposure, the introduction of mud and other debris was prevented using end caps fabricated of styrofoam, secured to the box panels using a combination of nylon tie fasteners and rubber bands. Nylon ties were also used to secure the box panel assemblies to the framing members located under the cargo bed of the truck (Figures 2, 3). The exposure intervals for the test vehicle were defined in 15 day phases with each phase being equivalent to one year exposure in a representative U.S. Army tactical environment.[3] The box panels were inspected at the end of each phase. Failure of the box panels was defined as the appearance of blisters on the interior of the lap joint. The application rate was adjusted during testing from every phase to every third phase on the vehicle based upon the performance in the lap joint interior of the box panels and numerical agreement with other flags.

Simultaneously the 16 remaining panels were exposed to GM 9540P[4] using a cyclic corrosion test chamber. The standard 0.9% NaCl, 0.1%$CaCl_2$, 0.25% $NaHCO_3$ test solution was used. Plain carbon steel calibration coupons described in GM Standard Test 9540P and supplied by GM were initially weighed and subsequently monitored for mass loss at intervals set by the specification. Mass losses measured for steel coupons used for this test were within parameters stated in the GM specification. The 9540P test consists of 18 separate stages that include the following: saltwater spray, humidity, drying, ambient, and heated drying. The environmental conditions and duration of each stage for one complete 9540P cycle are given in Table 1. The panels were periodically observed for the appearance of blistering using the same method described above. The duration of the chamber exposure was 100 cycles.

Results

Test Track at ATC

The 8 box panels with CARWELL were secured to the test vehicle at the beginning of the 4th phase. At the end of each phase, the panels were removed, rinsed of debris from the track using water, and then observed for corrosion damage on the interior surfaces of the lap joint (Figure 4). At the end of 4 phases, minute blisters <2 mm diameter were observed on 2 of the test panels (Figure 5). With each subsequent observation, blister nucleation was observed on additional panels. At the end of 6 phases, 4 additional panels were blistered. At the end of 7 phases, (10 phases total for the vehicle) all 8 panels had varying degrees of damage due to blisters on the panels.

GM 9540P

The 16 panels, 8 with CARWELL, 8 without treatment were tested in the cyclic saltspray chamber and observed for damage in the lap joint. After 10 cycles, before any damage was observed, it was noted that the oily "wet look" characteristic sheen of the CARWELL treated panels was no longer visible. The treated panels were now identical in appearance to the untreated ones. Panels were observed twice weekly at solution mixing. At 51 cycles, the first damage observed was blistering in the lap joint crevice on 4 of the untreated panels. The blisters appeared noticeably larger than any of the blisters observed on the test track panels however. Blister growth proceeded rapidly on the untreated chamber panels vs. equivalent exposure time from nucleation on the CARWELL treated test track panels. At 59 cycles, (1 additional year of tropical equivalent exposure) 6 of 8 untreated panels showed blistering in varying degrees of severity, all equal to or greater than observed test track damage. At 67 cycles, all of the untreated panels were blistering. At 74 cycles, the first blistering was observed on 3 of the treated panels. Blistering growth on the treated panels was also rapid but characterized by more localized corrosion with portions of the crevice remaining unaffected (Figure 6). As the exposure progressed, effects such as blistering that began on the interior of the joint became visible on the exterior, most notably on the untreated panels (Figure 7). At the conclusion of 100 cycles, all of the treated panels were blistered but less severely than the untreated panels.

Discussion

The test track panels endured exposure with the first minute signs of blistering observed at the end of the fourth phase. A TACOM study of CARWELL treated components at Cape Canaveral, FL outdoor exposure site indicated that under normal conditions Carwell can be applied every calendar year with good results.[5] In even more extreme environments such as found on islands in the tropics or during transport by cargo vessels across oceans, an application every six months could be warranted. In relatively benign areas, two years is the longest that was found to remain effective. The appearance of the blisters on the test track panels at the end of 4 phases while equivalently longer than durations observed by TACOM was not drastically different when compared with the typical fielded environment model. Therefore, a re-application rate at an interval of no greater than 3 phases of the ATC accelerated corrosion test (or 3 equivalent "years" in a typical tactical environment) is reasonable, based upon the early onset of corrosion in the box panels.

For the chamber panels, the addition of CARWELL inhibitor had a positive effect on the box panels. The onset of lap joint crevice blistering was delayed by 23 cycles, a relative lifetime increase of ~45%. In addition, the blistering, once established, was less widespread across the length of the lap joint. Despite the visual disappearance of the oil component at 10 cycles, CARWELL treatment appears to have a residual inhibiting effect.

Nucleation of the lap joint blisters appeared much sooner on the test track panels, 4 years equivalent test track vs. 9 years equivalent GM 9540P. The earlier appearance of the blisters may have been due to factors unique to the test track such as particulate contamination, vibration factors, inherent weather conditions, and greater moisture retention from less dry time. The severity of the corrosion in the lap joint of the test track panels @7 phases (7 years Army equivalent) was also greater than for the test chamber at 56 cycles (7 years Tropical equivalent) which had not blistered at that point of exposure. The duration of the chamber test was 100 cycles, in order to achieve the same exposure duration, the vehicle box panels will be run approximately 6 more phases to achieve the same equivalent exposure. If the exposures of the CARWELL treated panels are normalized to the initial appearance of blisters, the growth of the blisters in equivalent years in the chamber is greater than for the test track.

Conclusions

1. Initial blister damage appeared at phase 4 on the test track. Based upon this observation and findings from previous outdoor exposure conducted by TACOM, a re-application rate at an interval of 3 phases of the ATC accelerated corrosion test (or three equivalent "years" in a typical tactical environment) is reasonable, based upon the early onset of corrosion in the box panels.

2. The application of CARWELL to box panel specimens was beneficial in interior crevice areas such as the lap joint in GM 9540P cyclic saltspray and delayed the onset of blister damage by 23 cycles, an extension of 45% based upon elapsed cycles in the chamber.

3. The initiation of blistering on the CARWELL test track panels in equivalent exposure years was much sooner than for CARWELL treated chamber specimens.

4. ARL has not evaluated the effectiveness or suitability of using CARWELL on exterior, unenclosed CARC coated surfaces, and makes no recommendation for its use in this manner.

References

1. Box Panel Specimen, "12" X 12" Box Interior Cavity" Courtesy of RJD, ACT Laboratories, Hillsdale, MI, 18 May 1995.

2. MIL-C-53039A "Coating, Aliphatic Polyurethane, Single Component, Chemical Agent Resistant." 23 November 1988.

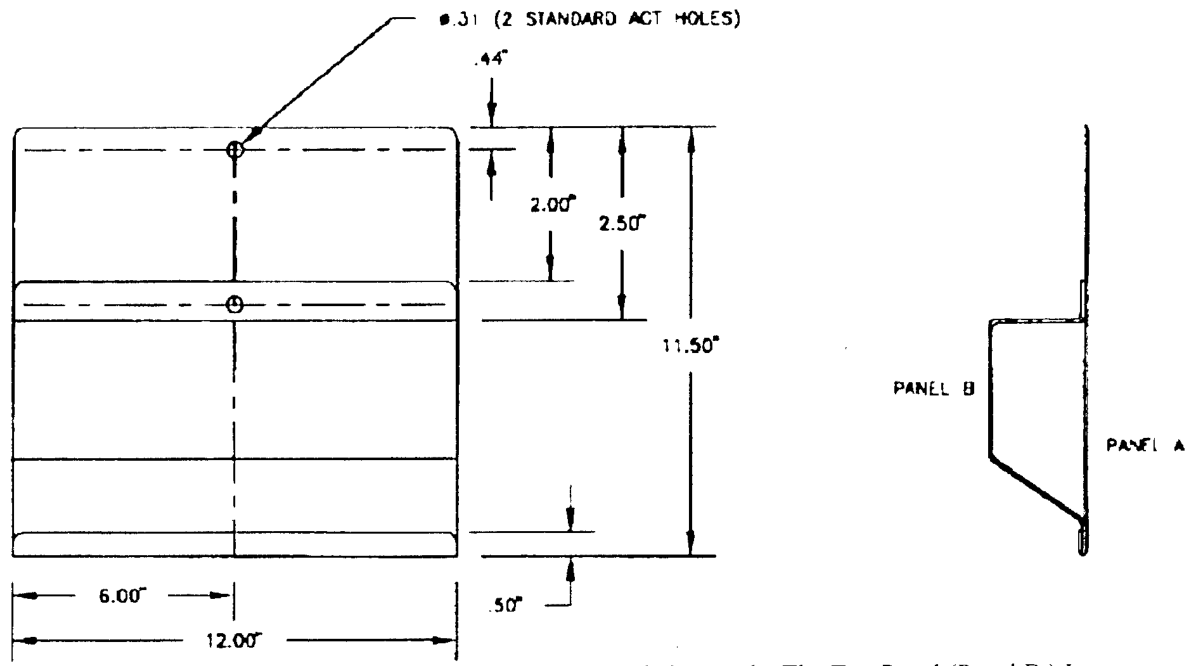
3. S. King, "U.S. Army Aberdeen Test Center Accelerated Corrosion Test Facility" U.S. Army Research, Development, and Acquisition, Jan/Feb, 1999 pp. 41-43.

4. General Motors Engineering Standards, Accelerated Corrosion Test, GM9540P, July, 1991, pp. 1-5.

5. I.C. Handsy, Excerpts from discussion of 2 year outdoor exposure study to determine application intervals for Carwell petroleum based corrosion inhibitor, 1998.

Table 1: GM 9540P Cyclic Corrosion Test Details

Interval	Description	Interval time (min)	Temperature (+/-3C)
1	Ramp to Salt Mist	15	25
2	Salt Mist Cycle	1	25
3	Dry Cycle	15	30
4	Ramp to Salt Mist	70	25
5	Salt Mist Cycle	1	25
6	Dry Cycle	15	30
7	Ramp to Salt Mist	70	25
8	Salt Mist Cycle	1	25
9	Dry Cycle	15	30
10	Ramp to Salt Mist	70	25
11	Salt Mist Cycle	1	25
12	Dry Cycle	15	30
13	Ramp to Humidity	15	49
14	Humidity Cycle	480	49
15	Ramp to Dry	15	60
16	Dry Cycle	480	60
17	Ramp to Ambient	15	25
18	Ambient Cycle	480	25



Box Interior Cavity Assemblies Are Constructed From Two 9x9" Panels. The Top Panel (Panel B.) Is Joined at a 90 Degree Angle With 1/2" Seam 2.5" From the Top of Panel A. The Two Panels Are Joined With a Hemflange Seam at the Bottom. Ends May Be Opened or Closed. (*ACT Laboratories*)

Figure 1: Box Panel Specimen Specifications

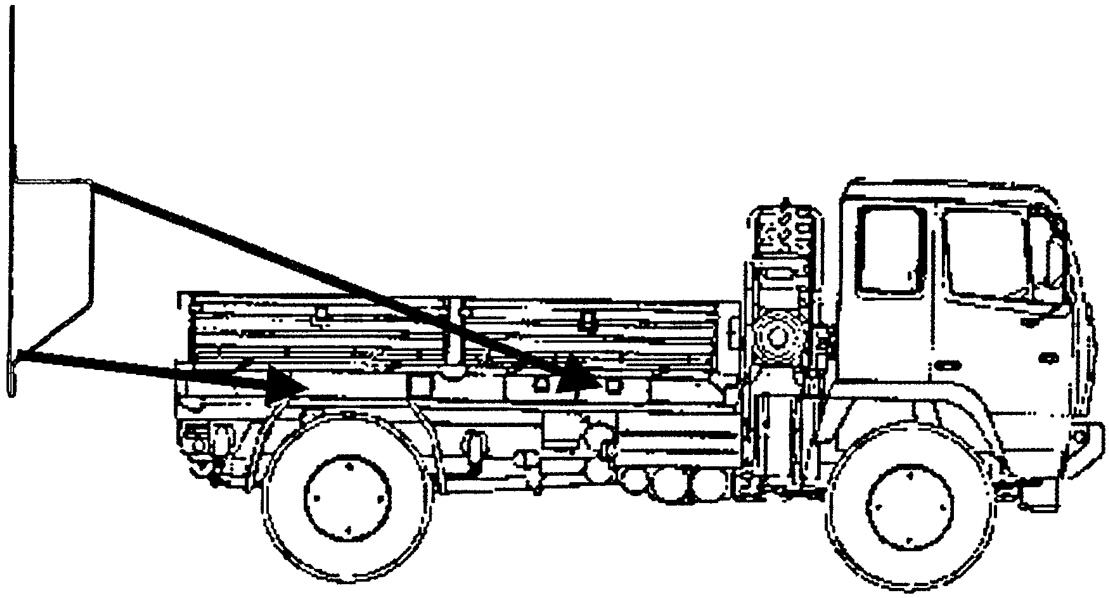


Figure 2: Test Vehicle Mounting Locations – 4 Specimens per Side

Figure 3: Mounting configuration for the CARC coated box panels. Panels are located under the vehicle cargo bed on each side, along the frame rails in two locations, one near the wheel well and one near the front of the cargo bed.

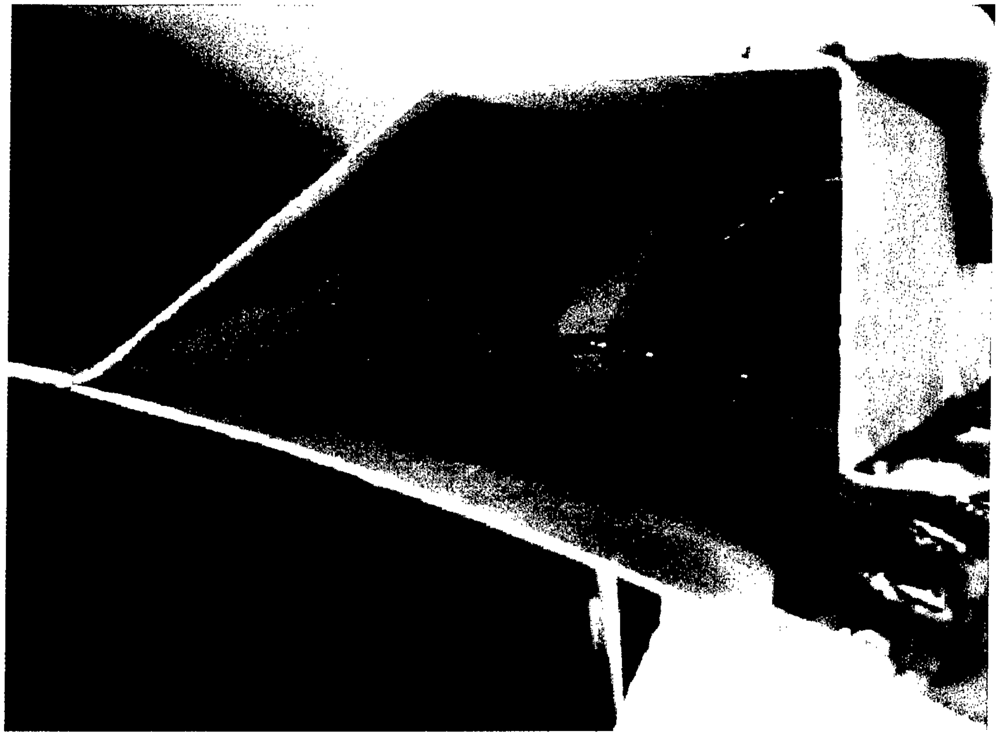


Figure 4: Crevice area after two phases (two equivalent years) of testing on the ATC Test track, approximately six weeks testing time. No visible corrosion products.

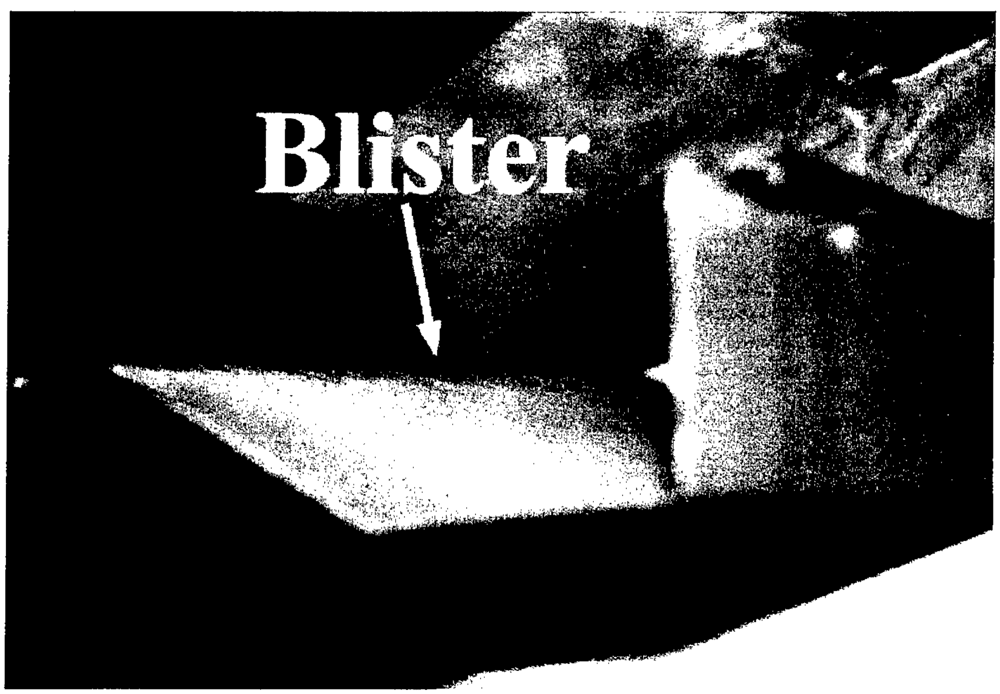


Figure 5: Crevice area after four phases (four equivalent years) of testing on the ATC Test track, approximately twelve weeks testing time. First visible blister.

Figure 6: Crevice area after 95 cycles GM 9540P (12 equivalent years) of testing with large localized blisters.

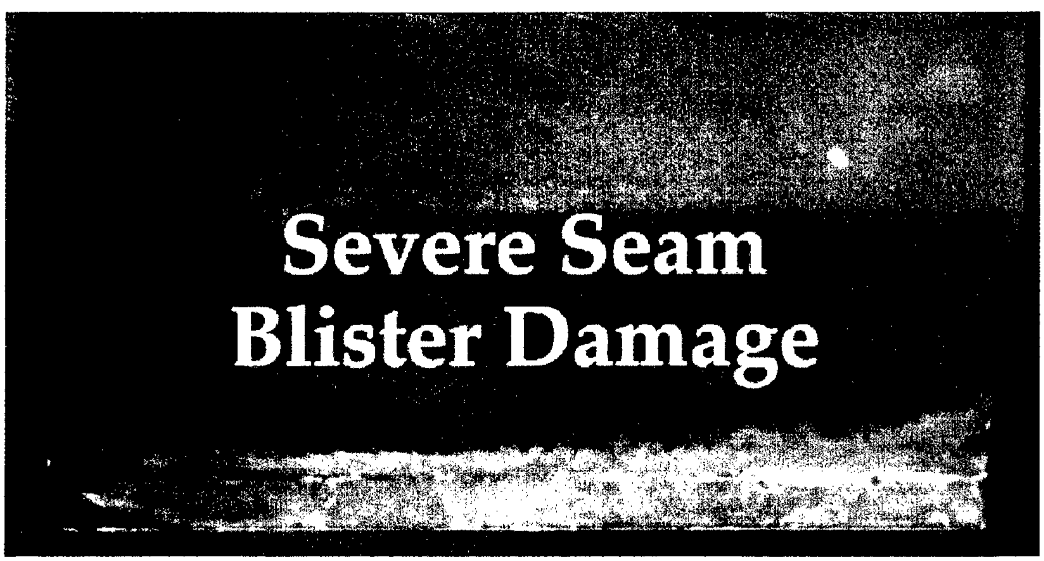


Figure 7: Severe exterior lap joint damage appearing subsequent to severe interior blistering.

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